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13. ABSTRACT (Maximum 200 words)

This report results from a contract tasking Institute of Atomic Physics -IFTAR as follows: The contractor will investigate advanced X-Ray sources for possible use in X-Ray schemes. In order to complete this task the contractor will perform a literature search to identify appropriate X-Ray sources. He will then develop sc to adapt these sources to available pulsed-Power generators. Each scheme will be analyzed to determine the critical parameters which limit performance.

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Dear Dr.Stickley,

Please find enclosed a copy of my final report on **STUDY OF THE COUPLING EFFICIENCES OF ADVANCED X-RAY SOURCES OF GAMMA-RAY LASER MEDIA**, contract F61708-96-W0276.

I will be very grateful if you would confirm me the receive of this report.

Yours most sincere

Ioan-Iovitz Popescu

Popescu

Phase 1 Basic Research on Induced Gamma Emission (IGE)

Contract F61708-96-W0276

Final report

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Title of Research: **STUDY OF THE COUPLING EFFICIENCES OF ADVANCED X-RAY SOURCES OF GAMMA-RAY LASER MEDIA**

The production of pulsed intense electron beams in table top devices is important for the development of compact intense X-ray sources. Perhaps one of the most dynamic development in this direction was achieved by using high voltage transient discharges in gases. Since the electron generation, electron acceleration and self-focused beam propagation are intimately correlated in the frame of a common mechanism, these devices are very compact.

The pseudospark [1], the channel-spark [2], and more recently, the preionization controlled open ended hollow cathode configuration (PCOHC) transient discharge device [3-5] are among such devices the most advanced. The typical parameters of the electron beams produced in these devices are: beam current of 100 A - 1 kA, beam duration of 10 - 100 ns, electron energy in the range of a few keV to the energy corresponding to the maximum applied voltage (10 - 30 kV), beam diammeter of about 1 mm, power density of 10^8 - 10^9 W/cm^2 and repetition rate of tens of Hz.

In a PCOHC device the main high voltage discharge takes place between an open ended hollow cathode 30 mm in diameter, and a plane anode [6-8]. In the multielectrode configuration, there are in addition five plane electrodes each 2 mm thick, with 2 mm central bore holes, separated by disk shaped insulators each 3 mm thick, with 10 mm bore holes (Fig.1).

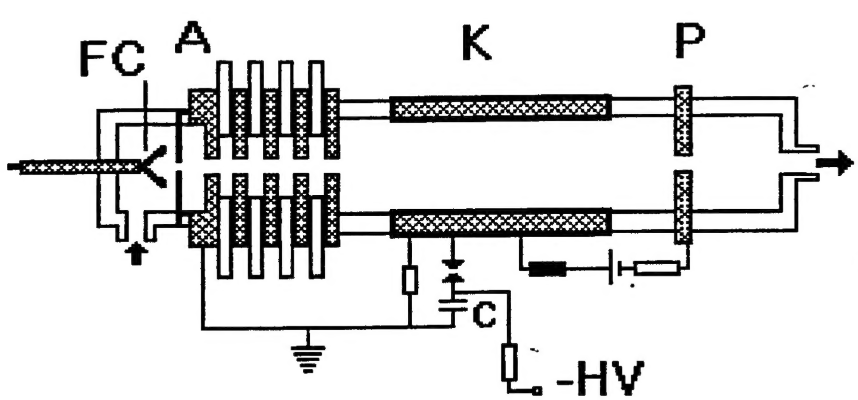
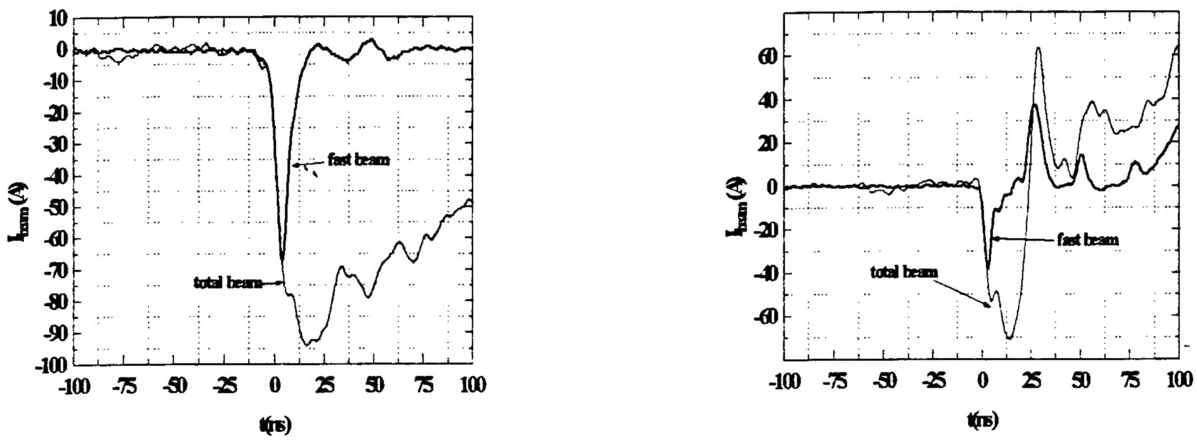


Figure 1. PCOHC geometry with multielectrode configuration, electrical circuit and device for beam current measurements (FC - Faraday cup; A - anode; K - open ended hollow cathode; P - preionization electrode; C - external capacitor; HV - high voltage supply).

The first 4 electrodes are floating and the last one is connected to the external capacitor (0.5 - 2 nF), playing the role of the anode. A spark-gap in the selfbreakdown mode was used to close the main discharge circuit. In most experiments, the working gas was air at pressure in the range 0.05 - 0.3 torr. For a given pressure and geometry, there is an optimum preionization current that matches the electron beam parameters. The geometry and implicitly the self capacitance of the electrode configuration have a direct and important influence on the fast electron beam parameters.

In Figure 2 typical electron beam currents (fast and total) are presented for single gap (Fig.2b) and multigap configurations (Fig.2a).



a

b

Figure 2. Fast and total beam currents for similar applied voltages (22 kV maximum applied voltage, 75 ns FWHM) in multigap (a) and single gap (b) configurations; working gas: air (0.1 - 0.3 mbar), D.C. auxilliary discharge of 0.25 mA (a) and 1 mA (b).

The beam currents were obtained for similar voltage pulses (22 kV breakdown voltage and 75 ns FWHM). The multigap fast beam current has a maximum value of 80 A, larger than the one obtained in the single gap configuration (40 A). The maximum total beam current is also increased in the multigap configuration (100 A) in comparison with the one obtained in the single gap configuration (75 A).

In PCOHC with multielectrode geometry we realized the beam parameters obtained in the pseudospark under similar conditions of input energy, gas pressure and diameter of the electrode bore holes. It is very interesting to note that, even though the maximum discharge current and its oscillation period depend on the value of the external capacitor (from I = 375 A for C = 0.5 nF to I = 750 A for C = 2 nF), the maximum beam currents (total and fast) are practically the same for each value of the external capacitor between 0.5 and 2 nF (Fig. 3a and 3b). The slow decreasing of the total beam current for an oscillating form of the discharge current was either attributed to a diffusion of the electron current of the discharge through the anodic aperture [9], or to a beam induced plasma formation in the drift tube [10].

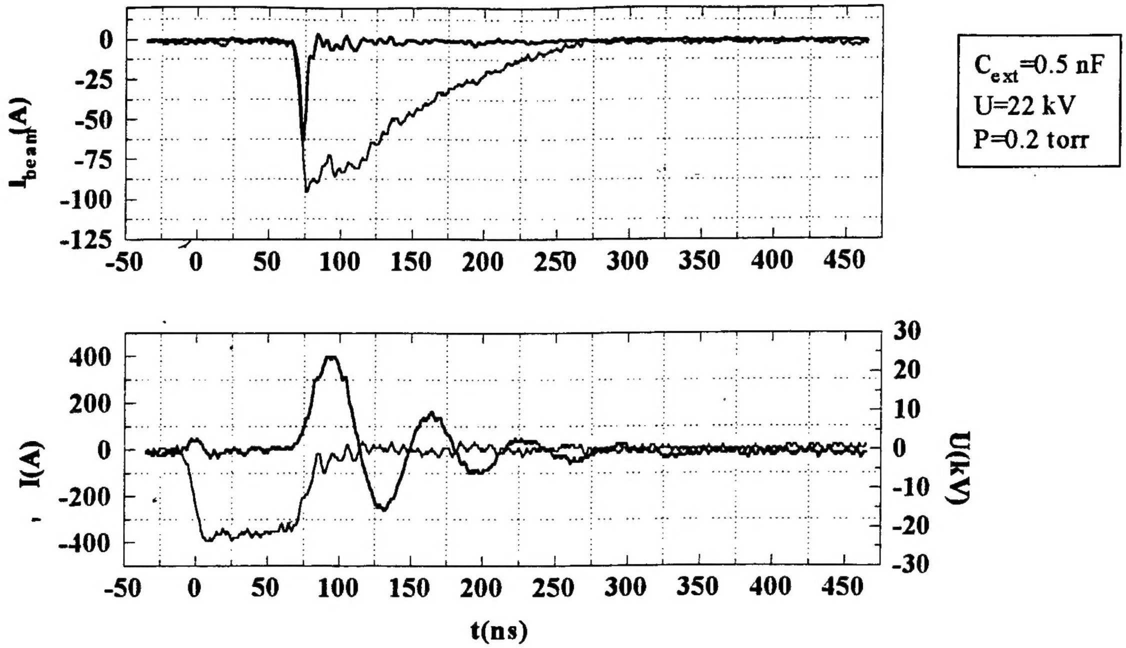


Figure 3. a) Typical oscillograms for the fast beam current, total beam current, discharge current and discharge voltage for C = 0.5 nF.

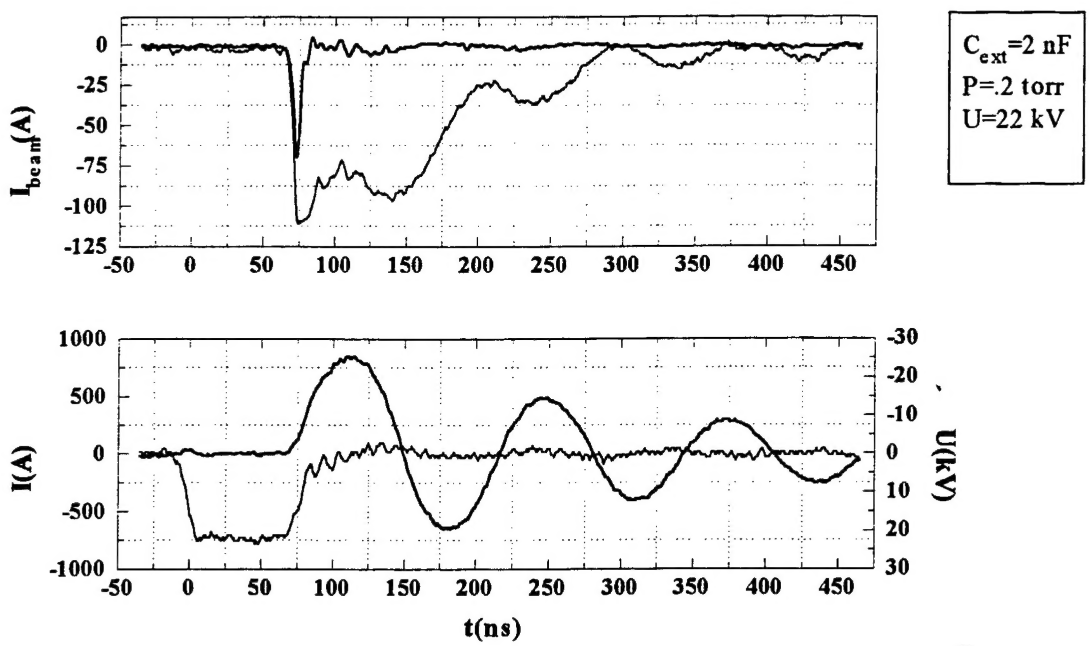


Figure 3. b) Typical oscillograms for the fast beam current, total beam current, discharge current and discharge voltage for C = 2 nF.

The PCOHC, which has an open ended hollow cathode, can also be used with a dielectric cathode [3]. In this case, the later phases of the discharge, which appear after the electron beam phase, are strongly suppresed. That means a longer life time for the cathode,

which is not damaged by the high currents concentrated in small spots, characteristic to the later phases of the discharge.

The geometry of the cathode and the presence of the small current (few mA) preionization discharge, which assures a constant number of charge carriers for the main discharge (400 - 800 A), determine a high reproducibility in the electron beam parameters from one shot to another. Apart from the measurements made with the Faraday cup, the most reliable measurements on the reproducibility of the high energy electron beam were realized by recording the X-ray emission from the interaction of the electron beam with a thin Al foil (25 μm). The X-ray pulses were recorded with a fast scintilator-PM system; the peak values were reproducible in 20% and the FWHM in less than 5%.

The X-ray source diameter, meaning the diameter of the high energy electron beam, was estimated from X-ray pinhole measurements. The pinhole was made of Pb and had a 0.1 mm diameter. Due to the foil absorption, only radiation with energies higher than approximately 5 keV was measured. After about 10,000 shots the diameter of the spot recorded on the X-ray film was only about 0.4 mm. This measurement provides a clear information on the high spatial stability of the beam.

In this way one can obtain intense point-like X-ray sources strongly coupled with the material to be irradiated; in the extreme case the material itself can be the target for the electron beam. Hence, these nanosecond, intense, point-like sources can be attractive for fundamental studies concerning the induced gamma emission in small quantities of isomers.

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